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Alternative cosmologies

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Abstract. A few remarkable examples of alternative cosmological theories are shown, ranging from a compilation of variations on the Standard Model (inhomogeneous universe, Cold Big Bang, varying physical constants or gravity law, zero-active mass, Milne cosmology, cyclical models), through the more distant quasi-steady-state cosmology, plasma cosmology, or universe models as a hypersphere such as the Dynamic Universe, to the most exotic cases including static models with non-cosmological redshifts of galaxies.

Most cosmologists do not usually work within the framework of alternative cosmologies very different from the standard one because they feel that these are not at present as competitive as the standard model. It is true that they are not so developed, but that is because cosmologists do not work on them. This vicious circle is to a great extent due to a sociological phenomenon known as the "snowball effect", in which resources are distributed to the most successful theory at a given time; the effect acts as a potential in a field that attracts cosmologists, causing funds, research positions, prestige, telescope time, publication in top journals, citations, conferences, and other resources to be dedicated almost exclusively to standard cosmology.

1 Some examples of alternative cosmologies

NOTE: This section contains some parts of chapter 2 of the book Fundamental Ideas in Cosmology. Scientific, philosophical and sociological critical perspectives *published with IOP Publishing [1].*

With few exceptions (e.g., [2, ch. 7]), academic books on cosmology usually describe only the standard model and do not mention alternative theories. There is however a rich variety of alternative ideas that merit consideration. Here I will offer a sample of these alternative models; due to their vast number, it is impossible to mention all of them in a single article. However, this sample is large enough to provide an idea of the theoretical approaches being discussed in cosmology. Defending any particular theory against standard cosmology or globally criticizing it is not my purpose here, although I may mention some aspects that are being debated concerning them. Here, I just review the literature and offer a classification of the different models, much as a botanist or zoologist classifying different species might do. The wild fauna and flora of cosmologists indeed encompass a wide spectrum of colorful suggestions.

I will mention some of the most remarkable models in the scientific literature of recent decades and also some contributions of minor impact, mostly coming from professional physicists or astronomers. There is also a vast literature produced by non-professional and amateurs who try to open new routes within the golden odyssey of cosmological model creation, but very few of them will be mentioned here. They are examples of curious ideas which, although not fully developed, could be the seeds of competitive models when they are further elaborated.

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To a greater or lesser extent, all of these alternative models suffer from a lack of development in comparison with the standard ΛCDM, so the first thing we must take into account when reading this section is that they naturally cannot compete with the standard model in all aspects because many of these alternative ideas are in the hands of very few individuals—occasionally only a single individual—who cannot produce hypotheses and ad hoc refinement of them to fit the ever increasing deluge of observational data at the same speed as the thousands of researchers working on the standard model. In science and philosophy, a hypothesis is *ad hoc* when it is added to a theory after (not before) the comparison with some observation or experiment in order to save this theory from being falsified. I will further elaborate the sociological matters in the section 2 of this article. In any case, it may happen that an alternative theory might explain certain aspects of some observational data better than the ΛCDM model; moreover, even if it fails to explain other types of observations, it might be only a matter of time and ad hoc speculation of the existence of new unknown/dark elements for it to be made to fit those data too. One might say that, in a certain sense, cosmology is a game whose purpose is to invent new fantastic creatures—not gods as in a religion, but mathematical abstractions that have a similar wildcard function—which can adapt our inherently prejudiced worldview to the reality.

1.1 Variations on the Standard Model

The present day standard model of cosmology gives us a representation of a cosmos whose dynamics is dominated by gravity (Friedmann equations derived from general relativity) with a finite lifetime, large scales homogeneity, expansion and a hot initial state, together with other elements necessary to avoid certain inconsistencies with observations (inflation, non-baryonic dark matter, dark energy, etc.). There are also other models that are closer to the main characteristics of the standard model, but they differ in some minor aspects. Many of these models are indeed investigated by some mainstream cosmologists. They are alternative models that stem from the variations on the standard model. Here are some examples:

- Rather than new cosmological models, there are multiple proposals for keeping the fundamentals of the standard model as stated before the 1980s and looking for variations in the type of dark matter, the different equations of state of dark energy or even without dark energy, or the hundreds of variations on the type of inflation or alternative proposals such as cosmic strings, walls and other textures. There are also variations in the number of neutrino families for nucleosynthesis; the formation of structures in a monolithic way (galaxies all forming at once) rather than the standard hierarchical scenario (galaxies being formed in continuous episodes of accretion and merging), etc. I do not think these are truly 'alternative' cosmological models; rather, they can mostly be embedded in the same classical Big Bang paradigm with the same fundamental pillars except for the final developments for the specific ΛCDM model.

- Inhomogeneous universe. The density distribution of the universe is not homogeneous on very large scales. It may obey a fractal distribution (e.g., Refs. [3, 4]), when the mass within a sphere of radius R is not proportional to R^3 for large enough R (in the regime in which there should be homogeneity), but proportional to R^D with a fractal dimension $D < 3$. There is little theoretical background to support a cosmology of these characteristics, but some observations may point in this direction.

- Cold Big Bang. This theory evolved from the 1960s [5]. Rather than a very high temperature at the beginning of the universe with later progressive cooling, the universe starts with $T = 0$ K. Explanations are offered for the origin of the light elements in primordial and/or stellar nucleosynthesis [6], the cosmic microwave background radiation [7] in terms of thermalization by intergalactic particles—a mixture of carbon/silicate dust and iron or carbon whiskers—of stellar radiation originating in Population III (further details of this idea are given in §1.3), and other phenomena explained by the standard Hot Big Bang.

- Variations or oscillations of physical constants (c, G, h, the fine structure constant, or others) with time or distance. For instance, Goldman *et al.*[8] propose variable G with distance, with which they explain the apparent variation of Ω with the scale with no need of dark matter; or different cosmological models with a variable speed of light c over time [9, 10, 11, 12] (see also the model of Sect. 1.2.2) or other variables [13], or several physical constants varying at the same time [14]. The consequences differ according to the models. They preserve the basic aspects of the standard model while keeping expansion and finite time since the beginning of the universe, but they change with regard to a number of characteristics [15].

- Modifications of aspects of the gravity law. These theories not only change G, but also the gravity force equation. There are dozens of such alternative theories which I will not mention here. They can be found in other reviews (e.g., [16]).

  The most popular alternative gravity theory is the modification of gravity law proposed in 'Modified Newtonian Dynamics' (MOND) [17, 18, 19, 20], which modifies the Newtonian law for accelerations lower than $\sim a_0 \approx 1 \times 10^{-10}$ m/s^2. This was in principle a phenomenological approach. Its proponents attempted to incorporate elements that make it compatible with more general gravitation theories; for example, the AQUAdratic Lagrangian theory (AQUAL) [21] or the Quasi linear approximation of MOND (QMOND) [22], which expanded MOND to preserve the conservation of momentum, angular momentum, and energy, and follow the weak equivalence principle. A relativistic gravitation theory of MOND was developed under the name Tensor-Vector-Scalar (TeVeS) [23], which also tried to provide consistency with certain cosmological observations, including gravitational lensing.

  A different alternative gravity theory with a certain impact is scalar-tensor-vector gravity, known as modified gravity (MOG, [24]). Another family of theories is the $f(R)$ gravity group, which modify general relativity by defining a different function of the Ricci scalar [25]. Other proposals include the dependence of space-time on curvature in a non-metric theory of gravity [26], or an interpretation of Mach's principle in which the rotational reference frames for stars in galactic orbits has a relationship to the rotating matter in the local galaxy and/or distant galaxies [27]. There are many others [16]: Einstein-ether theory, bimetric or general higher-order theories, Hořava-Lifschitz gravity, Galileons, Ghost Condensates, and models of extra dimensions, including Kaluza-Klein, Randall-Sundrum, Dvali-Gabadadze-Porrati model with 4D gravity on a brane[1] in 5D Minkowski space, or higher co-dimension braneworlds, Weyl conformal gravity (invariant under Weyl transformations [28]), etc.

  The cosmological implications of theories that modify the law of gravitation are important, but most of them are underdeveloped. There are several variation of MOND/TeVeS. Felten [29] does not accept that a MOND-cosmology might be possible, stating that a quasi-Newtonian calculation adapted from Newtonian cosmology suggests that a MOND universe will recollapse and/or fail to satisfy the cosmological principle of a homogeneous universe. Other authors claim that a MOND-cosmology can be built [30, 31] that results in a uniform expansion and homogeneity on the horizon scale consistent with MOND-dominated non-uniform expansion and the development of inhomogeneities on scales out to a substantial fraction of the Hubble radius. Primordial nucleosynthesis, with its concomitant thermal and dynamical history of the universe, is identical to that of the standard cosmological model until matter dominates the energy density of the universe, a moment in which the MOND cosmology diverges from that of the standard model. Other gravity variations may involve other considerations, but basically they try to preserve the global aspects of the standard cosmology.

- $R_h = ct$. Instead of the particular solutions of ΛCDM with fixed parameters $\Omega_m \approx 0.3$, $\Omega_\Lambda \approx 0.7$, the FLRW may have other solutions. One remarkable case that has generated a large number of papers in recent years is the Zero-active mass condition, also called $R_h = ct$. This model was firstly proposed under the name of an 'Ur theory', which relates cosmology to particle physics and quantum theory [32], or a special (flat) case of an eternal coasting model [33], consistent with a scale factor proportional to cosmic time ($a(t) \propto t$) or equivalently an active mass $\rho + 3\frac{p}{c^2}$ equal to zero at all times, which, together with the ansatz $\Lambda = 0$, makes the acceleration of the expansion equal to zero for all times. The density is fitted to keep the universe flat. "Milne Cosmology" can be considered as a Zero active model, but with the particular case of $\rho = 0$. This strictly null density of matter is unrealistic since stars, gas and other components of the universe have mass and are real, but might possibly consider the density to be low enough to be considered close to zero, in comparison with the critical density in the standard model.

  The most important researcher defending this model nowadays is Fulvio Melia (1956-), who has produced dozens of papers with theoretical and observational support for the model (e.g., Refs. [34, 35, 36, 37]). There is the coincidence that now the deceleration of the Hubble–Lemaître flow is compensated by the acceleration of the dark energy; the average acceleration throughout the history of the universe is almost nil [34] and the size the universe is such as if there were constant

[1] In string theory and related theories such as supergravity theories, a brane is a physical element that generalizes the notion of a point particle to higher dimensions. Branes are dynamical objects that can propagate through spacetime according to physical laws of quantum mechanics.

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expansion. This coincidence supports the constant expansion ratio posited as $R_h = ct$. According to Melia, this model fits the data pretty well where ΛCDM does; moreover, it offers some further advantages at high z, where the standard model has some difficulties in concealing the existence of objects that usually need a long time to be formed in a very young universe that does not allow time for such evolution. $R_h = ct$ solves the problem because the age of the universe at redshift z, $t(z)$, is much greater in this model than with the standard ΛCDM. The Big Bang would have happened $H_0^{-1} = 14.57$ Gyr ago (for $H_0 = 67.4$ km/s/Mpc; [38]), longer than the 13.79 Gyr for ΛCDM with the same Hubble–Lemaître constant. There would have been no inflation. Interestingly, an even more remarkable difference from the standard model is the prediction that the Cosmic Microwave Background Radiation (CMBR) is formed at $z \approx 16$ by dust rethermalization of Population III stellar light [39], although with a major difficulty in justifying a perfect blackbody shape for that radiation, since we do not know of any kind of dust that produces such a flux shape.

- Cyclical universes. In the 'Conformal cyclic cosmology' model [40], based in the framework of general relativity, the universe iterates through infinite cycles, with the future timelike infinity of each previous iteration being identified with the Big Bang singularity of the next. So the Big Bang (although without inflation) applies to our present universe, but it is speculated that many other singularities happened previously and will happen after ours. The singularity of each is taken to be a smooth conformal continuation of the remote future of the previous one via an infinite conformal rescaling; there is no collapsing phase. The second law of thermodynamics, with the curious nature of its origin, is automatically incorporated, where Hawking evaporation of black holes provides a key ingredient.

  Another variation of the cyclical model proposed by Steinhardt and Turok [41] is an endless universe without beginning or end, an endless sequence of epochs that starts with a 'Big Bang' singularity (again without inflation) and ends in a 'Big Crunch' (collapse of the universe due to an excess of mass-energy of the critical density in a closed universe). Although the model is motivated by M-theory,[2] branes, and extra dimensions, the scenario can be described almost entirely in terms of conventional 4D field theory and 4D cosmology, with a continual cycle of expansion and contraction as parallel universes (or 'branes') collide.

  See also another cyclical model in Sect. 1.2.2, although away from general relativity and other features of the standard model.

All these models are variations based on the Lemaître–Gamow idea, all their supporters are *big-bangists*. But there are however other models that challenge the notions of a state of the universe with a singularity, unlimited density of matter-energy, or other important tenets of the standard model as proposed in the 1920s–1940s, as I show in the following sections.

1.2 Universe as a Hypersphere

1.2.1 Chronometric Cosmology and other non-cyclical cosmologies. Another category of models that have appeared in varying versions is one that posits that the geometric form of our universe is a hypersurface of three dimensions of an hypersphere with more four or more dimensions, that is, a set of points at a constant distance from its centre, constituting a manifold with one dimension less than that of the ambient space.

One of the first models maintaining this idea is the Chronometric Cosmology of Irving E. Segal (1918–1998) [42, 43]. This model assumes that global space structure is a 3D-hypersurface in a universe of four dimensions. Events in the universe are ordered globally according to a temporal order. This model makes an application of general relativity different from the standard model, getting a relationship of the redshift with distance r: $z = \tan^2 \frac{r}{2R}$. With data about redshifts of galaxies and distances, it is now known this cannot be correct [44]. His cosmology gives a good fit to the various curves versus redshift: magnitude, counts, angular size, etc., but, as mentioned, with the data of the Hubble–Lemaître law this statement is not sustainable, and there is no explanation for the CMBR. Many other refutations of Segal's claims have also been published [45, 46, 47, 48].

More recent is the hypothesis of the existence of a 5-dimensional spacetime combined. By making some peculiar assignments between coordinates and physical distances and time, a hyperspherical symmetry is made apparent by assigning the hypersphere radius to proper time and distances on the hypersphere to usual 3-dimensional distances in a Euclidean universe [49], which can explain the Hubble–Lemaître expansion law without appealing to dark matter; an empty universe will expand naturally at a flat rate in

[2]M-theory unifies all consistent versions of superstring theory.

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this way. Another variation is the Hypersphere World-universe Model [50, 51], which claims the existence of a 3-dimensional hypersphere with respect to to a 4-dimensional Nucleus of the World. Matter in this universe is of the ordinary kind with the addition of a multicomponent dark-matter (instead of Cold Dark Matter plus Dark Energy). This model has a number of peculiar characteristics: the beginning of the universe, instead of originating from a singularity, stems from a 4-dimensional Nucleus of the World; the radius of this Nucleus, increasing with speed c, is what produces the expansion; the CMBR stems from the thermodynamic equilibrium of photons with intergalactic plasma; and the nucleosynthesis of light elements occurs inside dark matter cores of Macro-objects.

1.2.2 Dynamic Universe. "Dynamic Universe" (DU) by Tuomo Suntola [52, 53] is another type of model of Universe as hypersphere, introducing also an eternal cycle, similar to "Conformal cyclic cosmology" or Big Bang–Big Crunch series but without FRLW metric. Here, the space is represented as a spherically closed whole: space as the 3D surface of a 4D hypersphere expanding at velocity c; all locations in space are at about 14 billion light–years distance from a "starting point in common" in the fourth dimension. Due to faster expansion rate in the past, the age of the expanding space is about 9.3 billion present years (this is not in conflict with age of oldest stars and clusters, but they are lower than usually determined due to variation of c with time). There is as contraction–expansion cycle from infinity in the past to infinity in the future or in repeated cycles passing the "essential infinity". DU also allows a finite number of cycles. Inertial work is the work done against the global gravitational energy as the interaction in the fourth dimension, which constitutes a quantitative expression of Mach's principle.

The dynamics is governed by a Zero–energy principle, by which the sum of kinetic energy plus potential energy is always zero:

$$E_{\rm kin.} + E_{\rm pot.} = M_{\rm surf.} c^2 - G\, M_{\rm surf.} \frac{M"}{R_4} = 0,$$

where $M" = 0.776\, M_{\rm surf}$ is the equivalent mass if it were situated in the center of the hypersphere; $M_{\rm surf.}$ is the mass in the 3D hypersurface=space; R_4 is radius of the 4-D hypersphere; c (speed of light)=c_4 (speed of expansion of the hypersurface)=$\sqrt{G\, M"/R_4}$; $c_0 = \frac{dR_4}{dt} = \frac{2R_4}{3t}$; $E = m\, c^2$ for each particle of mass m, so its energy decreases with time.

There is also here a reformulation of Planck's equation:

$$E = h\,\nu = (h_0\, c_0)\frac{c}{\lambda} = c_0\, m_\lambda\, c,$$

where the rest energy of mass is $m_\lambda = h_0/\lambda$, $h_0 = h/c_0$, which is the mass equivalence of a quantum of radiation, the counterpart of the Compton wavelength $\lambda_m = h_0/m$, the wavelength equivalence of mass m. Breaking down Planck's constant into its constituents opens up the essence of mass as wavelike "substance" for the expression of energy. Mass is not a form of energy, but it expresses energy related to motion and potentiality. In DU framework, mass is conserved also in annihilation; the mass equivalence of emitted photons is equal to the rest mass of annihilated particles. The total mass in space is a primary constant.

Suntola posits in this theory that there is an expansion of the local Universe, something different from the expansion in Big Bang model. The overall energy balance in space requires that all gravitationally bound local systems expand in direct proportion to the expansion of space. Therefore, it predicts that early planets were closer to the Sun in the past, and Suntola thinks it explains the existence of liquid water in Mars in the past or the higher temperatures of the oceans on the Earth. It also predicts a perihelion advance equal to that in general relativity. Atoms and material objects do not expand, but the distance Earth–Moon would be affected: 2.8 cm of the measured 3.8 cm annual increase of the Earth to Moon distance would come from the expansion of space and only 1 cm from tidal interactions. According to Suntola, the number of days per year in the Earth in the past is predicted and agrees paleo–anthropological data.

Among the predictions and comparisons with observations, there is an excellent match to the periods observed around Sagittarius A* at the center of the Milky Way; decay of binary star period (in agreement with general relativity prediction of eccentricity e larger than ~ 0.2), whereas for circular orbits ($e = 0$) there is decay in general relativity but not in DU; magnitude–redshift relation of SNIa matches observations accurately without dark energy, according to Suntola; predictions in agreement with observations of angular size test; $dc_4/c_4 = -3.6 \times 10^{-11}$ year^{-1}. However, there are also many caveats in the agreement of observation and predictions, and many aspects of observational cosmology that are not explained: gravitational waves in binary system, even with circular orbits (although with lower level of precision), look to confirm General Relativity and not DU; special Relativity (which assumes constant speed of light)

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never disproved; nucleosynthesis of light elements, CMBR, large-scale structure, dark matter issues, etc. not explained.

1.3 Quasi-Steady State Cosmology

Among the most developed models, with several professional researchers working on it over several decades, perhaps the alternative hypothesis of highest impact during the last century is 'Quasi-Steady State Cosmology' (QSSC), which was indeed first called the 'Steady State Cosmology' when it was a cosmological model competing at the same level of importance and impact with the Big Bang hypothesis. It was developed and defended for more than sixty years, and even today we cannot declare it dead, although its main supporters have passed away or retired, and the new generations of cosmologists no longer work on it, mainly owing to lack of socio–economic support (see Section 2).

This model is indeed something beyond a small variation on Lemaître-Gamow ideas. It is a radically different view, in which there is no beginning of the universe, but an eternal cycle of matter creation. The difference with the cyclical universes of §1.1 is that there is no singularity of state of infinite or unlimited density, and the moment of 'creation' is not unique, but is continuous and constant (in the Steady State version) or oscillating (in the Quasi-Steady State version).

Fred Hoyle (1915–2001), and independently Hermann Bondi (1919–2005) and Thomas Gold (1920–2004), proposed the hypothesis of the Steady State [54, 55][3] in which, contrary to the Big Bang approach, there was no beginning of the universe. The universe is expanding, it is eternal, and the homogeneous distribution of matter is being created at a rate of $\sim 10^{-24}$ baryons/cm^3/s owing to the existence of a putative ubiquitous C-field of matter creation, instead of the unique moment of creation in the Big Bang. The perfect cosmological principle of a universe being observationally the same from anywhere in space and at any time is maintained in this model, whereas the standard model only gives a cosmological principle in space but not in time. There is no evolution. The universe remains always the same. The matter distribution is homogeneous and the redshift is caused by the expansion of the space with a scale of $a(t) \propto e^{H_0 t}$. Newly created matter forms new galaxies that substitute those that are swept away by the expansion.

During the 1950s, both the Big Bang and Steady-State theories held their ground. While there were attempts to explain the abundances of the chemical elements with Gamow et al.'s theory, the Steady State Theory also provided plausible explanations. The abundances of the light elements (helium, lithium, deuterium, and others) were explained in terms of stellar nucleosynthesis and collision with cosmic rays in the remote past of the universe [57]. The heaviest elements could also be explained in terms of stellar rather than primordial nucleosynthesis, and the defenders of Big Bang in the end also had to adopt the stellar nucleosynthesis of Burbidge et al. for the heavy elements.

Nonetheless, the Steady State theory would lose competitiveness by the mid-sixties, because it could not explain certain observational facts. It could not explain why the galaxies were younger at higher redshift. Neither could it explain the excess of radio sources at large distances [58], or the distribution of quasars. Most importantly, it did not explain the CMBR as interpreted in cosmological terms in 1965. This strongly favored the Big Bang theory.

In 1993–94, Fred Hoyle, Geoffrey Burbidge (1925–2010), and Jayant Narlikar (1938–) published a modification of the model that was called the 'Quasi-Steady State' theory [59, 60, 61, 62]. The main modification consisted in positing an oscillatory expansion apart from the exponential term:

$$a(t) \propto \mathrm{e}^{t/P}[1 + \eta \cos(2\pi\theta(t)/Q)],$$

with a long time scale of expansion of $P \sim 10^{12}$ years, $\theta(t) \sim t$. The exponential factor had already been introduced in the first version of the Steady State model to keep $\frac{\dot{a}}{a}$ constant and consequently maintain a constant density of matter by invoking the continuous creation of matter. The new term here is the sinusoidal oscillation: smaller time scale oscillations have a period of $Q \sim 4 \times 10^{10}$ years. The exact value of the parameters Q and η would be determined from Hubble–Lemaître's constant, the age of globular clusters, and the maximum observed redshift in the galaxies. The time since the last maximum of $a(t)$ is $0.85Q = 14$ Gyr. With the parameters given in the original version of the QSSC theory, the maximum observable redshift should be around 5, although it would be increased later as the parameters changed to adapt to new observations. The creation of matter is confined to epochs with minimum $a(t)$ rather

[3] Indeed, prior to Hoyle, Bondi, or Gold, Albert Einstein attempted to construct a Steady-State model of the universe, as shown in one of his unpublished manuscripts [56]. The manuscript, which appears to have been written in early 1931, demonstrates that Einstein once explored a cosmic model in which the mean density of matter in an expanding universe is maintained constant by the continuous formation of matter from empty space. Einstein's Steady-State model contained a fundamental flaw and this was possibly the reason why he abandoned this line of research [56].

than being continuous. These creation events involve Planck particles and eventually make hydrogen gas plus the lightest elements, deuterium and the two isotopes of helium. Since the overall time scale is very long, many generations of stars (and galaxies) will evolve and die.

With the introduction of the Quasi-Steady variation, some of the problems that affected the original theory of 1948 were solved. This explained why there are younger galaxies at higher redshift, the problem of the radio sources, the distribution of quasars (with lower density for redshifts lower than 2.5), and the formation of large-scale structure (clusters, voids, filaments) [63]. Wright [64] complained that Hoyle *et al.* had not solved the problem of the radio sources completely, but Hoyle *et al.* [65] later replied that the question might be solved with a change of parameters.

The CMBR and its blackbody spectrum would be explained as the effect of the thermalization of radiation emitted by stars of the last cycle $P/3$ due to absorption and re-emission that produce iron needle-shaped particles ('whiskers') in the intergalactic medium. Because of the long distances travelled by the CMBR photons in the maxima of the oscillation and the thermalization that occurs at each minimum, there is no accumulation of anisotropies from one cycle to another. Only the fluctuations of the last minimum survive, which gives fluctuations of temperature comparable to the observed $\Delta T/T \sim 5 \times 10^{-6}$. First, the carbon needles thermalize the visible light from the stars, giving rise to far-infrared photons at $z \sim 5$, thus maintaining the isotropy of the radiation. Afterwards, iron needles dominate, degrading the infrared radiation to produce the observed microwave radiation [66]. Within QSSC, on the other hand, the anisotropies of this radiation would also be explained in terms of interaction of the radiation with clusters of galaxies and other elements [62, 67].

The existence of extragalactic iron whiskers might be formed in a process similar to metallic vapours cooling slowly enough in the laboratory. Whiskers are formed by this type of process during the expansion of the envelopes of supernovae. As a matter of fact, some of the defenders of the QSSC model [68] have claimed that iron whiskers are observed in the emission spectrum of the Crab pulsar PSR0531+21. Thermalization was also proposed to be due to the plasma of the intergalactic space, but in this case it takes about 450 Gyr for the starlight to get thermalized [69].

Summing up, in the 1990s QSSC competed with the standard cosmological model to explain many observations, at least in an approximate way, but with a very different description of the universe.

1.4 Plasma Cosmology

Plasma Cosmology is another alternative model that has occupied two or three generations of researchers, some of them still active today. Its proponents include the physics Nobel laureate Hannes Alfvén (1908–1995), Oskar Klein (1894–1977), Anthony L. Peratt (1940–), Eric J. Lerner (1947–), Ari Brynjolfsson (1926–2013). It has a strong argument against one of the main pillars of the standard model: It proposes an alternative to the belief that gravitation is the fundamental force that controls the dynamics of the universe. It assumes instead that most of the mass in the universe is plasma controlled mainly by electromagnetic forces (and also gravity, of course), rather than gravity alone [70, 71, 72, 73][74, ch. 6]. According to this theory the universe has always existed, it is always evolving, and it will continue to exist forever.

The plasma in the laboratory, through electric currents and magnetic fields, creates filaments similar to those observed in the large-scale filamentary structure of the universe. The plasma cosmology model predicts the observer morphological hierarchy: distances among stars, galaxies, cluster of galaxies, and filaments of huge sizes in the large-scale structure. The observed velocities of the streams of galaxies in regions close to the largest superclusters are coincident with those predicted by the model, without the need for dark matter [73]. The formation of galaxies and their dynamics would also be governed by forces and interactions of electromagnetic fields [73, chs. 1, 6][75, 76].

Hubble–Lemaître expansion was admitted in the first version of plasma cosmology and was explained by means of the repulsion between matter and antimatter [70, 77]. A plasma mechanism can separate matter from antimatter and, when an antimatter cloud bumps into an ordinary-matter cloud, they will not totally annihilate each other; instead, only a thin layer will be annihilated [78], generating a hot, low-density plasma layer which will push the clouds apart. Alfvén proposed his 'fireworks' model, in which a supercluster is repelled by other superclusters; within a supercluster each cluster is repelled by other clusters; and within a given cluster each galaxy is repelled by the other galaxies, and so on, obeying a distribution of matter and antimatter. In each local volume, a small explosion would impose its own local Hubble–Lemaître relationship, and this would explain the variations in the velocities of the Hubble–Lemaître law, i.e. the different values of the Hubble constant measured in the '70s and '80s, when Alfvén posited his hypothesis, in different ranges of distances or looking in different directions, all without invoking dark matter. The energy derived from the annihilation of protons and electrons would produce a background radiation of X- and γ-rays. There are some objections against the existence of antimatter based on the absence of γ-rays from anhilation, but they are model-dependent. Many of the objections against antimatter have been analysed [79] and it has been shown that none of them is crucial. Nonetheless, some critics remarked that it is not consistent with the isotropy of the X-ray backgrounds [2, ch. 7].

Instead of expansion caused by matter–antimatter repulsion, recently some proponents of plasma cosmology (e.g., Refs. [80, 81]) have stated that there is no expansion, that the universe is static, and that the redshift of the galaxies would be explained by some kind of tired light effect of the interaction of photons with electrons in the plasma.

With regard to the CMBR, Lerner [82, 83] explains it in terms of absorption and re-emission of radiation produced by stars. It is similar to the mechanism proposed by QSSC, but here the thermalization is due to interaction with electrons. The interaction of photons and electrons produces a loss of direction in the path of the light, giving rise to isotropic radiation.

1.5 Static Models and/or non-cosmological redshifts

At the farthest extreme of alternative models with respect to the standard cosmology, we have proposals of universe that contradict the main interpretation upon which standard cosmology was created from the 1920s onwards: expansion of the universe and the interpretation of redshifts as cosmological. Some versions of plasma and hypersphere cosmologies figure among these models, but there exist plenty of other models that are characterized by the lack of an origin of time (an eternal universe), and lack of expansion, in some cases the space even being infinite and Euclidean. The redshift of galaxies given by Hubble–Lemaître's law would be due to some mechanism different from the expansion or Doppler effect, mainly a 'tired light' (loss of energy of photons due to some interaction along their path) effect or others. I will not mention here the many cases of static and/or non-cosmological redshift models in the literature; see examples in [1, ch. 2].

Static models are usually rejected by most cosmologists. However, from a purely theoretical point of view, the representation of the Cosmos as Euclidean and static is not excluded. Both expanding and static spaces are possible for the description of the universe (see [1, ch. 2]).

1.6 Caveats/Problems in the Alternative Approaches

The standard model has many problems, many observations not being understood in the light of the predictions of the model [1]. The alternative proposals have their share of difficulties too, and their problems are yet more severe (see, for instance, Edward L. Wright's web-page[4]), perhaps because these theories are not as developed and polished as the standard model.

Solution of Olbers' paradox by dust absorption in an infinite universe, for instance, is not clear. One may wonder, if energy does not disappear, whether the absorbing element (dust) should be heated and re-emitted, or how can disappearance of energy be consistent with known physical laws. This problem has no easy solution. Expansion in eternal universes is considered a fact, so the models need speculative elements to argue that there was no beginning of the universe, or an alternative explanation for the redshift of the galaxies is needed, which raises its own set of difficulties. Also, light element abundances in some cases require very old populations (Population III) that have not been observed yet. The ΛCDM explanation of CMB has alternatives, but with ad hoc elements without direct proof, such as invented particles to thermalize stellar radiation. All proposals to explain a CMBR produced in the intergalactic medium—even assuming that a perfect black body shape can be produced—have the problem that the integration along the line of sight gives a superposition of many layers of black body radiations, each with a different redshift, giving in total something different from a black body, unless the CMBR originates in the local universe ($z \approx 0$; in such a case, the problem would be that the space would be too opaque to allow the observations of distant radio sources [64]) or at a given high redshift $z > 0$ but within a layer with small Δz.

The most elaborate alternative models, such as QSSC, do indeed apply the same methodology as the standard model: they have some basic tenets and a lot of free parameters and ad hoc elements that are introduced every time some observation does not fit their model. The modern version of QSSC is able to explain most of the difficulties of the previous (Steady State) version of the model. They introduce ad hoc elements without observational support (e.g., the oscillation of the expansion) in the same way that the standard model introduces ad hoc non–baryonic dark matter, dark energy, inflation, etc. The very idea of continuous creation of matter[5] also necessitates some very exotic physics, with no empirical support.

[4] http://www.astro.ucla.edu/∼wright/errors.html

[5] The idea of continuous creation of matter as a result of a modification of Einstein's equation of gravitational field is also independently explored by other alternative cosmological models (e.g., [84]).

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Furthermore, the maximum redshift of a galaxy was set to be 5 in the initial version of QSSC, but later it turned out that the theory can be made compatible with any redshift of a galaxy, by introducing a change of its free parameters.

My impression is that none of the alternative models has acquired the same level of development as ΛCDM in offering explanations of available cosmological observations. One should not, however, judge any theory according the number of observations that it can successfully explain, but by the plausibility of its principles and its potential to fit data, provided that we had an army of theoreticians able to correct the theory ad hoc every time new observations need to be accommodated. A pluralist approach to cosmology is a reasonable option when the preferred theory is still under discussion. Therefore, given the number of problems with the standard model [1], it is quite reasonable to keep a weather eye on alternative ideas that might at least provide better partial explanations of certain observed phenomena. Nonetheless, a global cosmological theory that fully explains everything in the universe does not yet exist according to either standard or in alternative viewpoints.

2 Sociological factors that hinder the development of alternative cosmological models

NOTE: This section contains some parts of chapter 8 of the book Fundamental Ideas in Cosmology. Scientific, philosophical and sociological critical perspectives *published with IOP Publishing [1].*

There are many individuals, scientists and non–scientists alike, who believe that science is an open process in which the best ideas are quickly recognized and accepted, while the erroneous ideas are immediately discarded. They think that a researcher could be working hard in a laboratory or observatory, or developing some theoretical idea and, on making a revolutionary discovery, would cry, 'Eureka! Eureka!' as astonished colleagues welcome the new idea, immediately recognizing its merits.

Such a vision is naïve and is far from the way in which ideas are usually accepted—even less so when talking about cosmology these days.

Cosmology today has become almost closed to discussion of theoretical models that stray too far from the standard model, not because the model is perfect or because the fundamental ideas of alternative models have been definitively rejected, but for other, non-scientific, reasons. Small variations of the standard model (see §2.1) are given an ear, but not the most outrageous proposals that challenge the basic dogmas, starting with the expansion of the universe. Some authors have even considered the term 'alternative cosmology' as a pseudoscience on a par with 'alternative medicine' [85, footnote 33]. Cosmologists do not usually work within the framework of exotic alternative cosmologies and they do not pay attention to them because they feel these models are not at present as competitive as the standard model. They are certainly not so well developed for the simple reason that cosmologists do not work on them. It is a vicious circle. Furthermore, the machinery of science is becoming more and more collective, moving away from individual scientific adventures. The scientist is more like a small cog in a big machine than a free intellectual. Most scientists are busy with administrative and routine tasks within predetermined projects, trying to navigate the system, leaving them little time to explore new ideas or study the ideas of people that have scant recognition.

The fact that most cosmologists pay no attention to alternative ideas and dedicate their research time exclusively to the standard model is to a great extent owed to sociological considerations. It is therefore worth devoting some thought to the social structures in cosmological science. I am not saying that the universe is a social construct (a typical postmodern idea). Quite the contrary: the universe exists independently of our human affairs and some of its properties are derivable with our scientific analyses. However, human and social factors play an important role in the selection of theories, and this is perhaps the most important factor in the case of cosmology.

2.1 Cosmological models and free parameters: new epicycles?

The number of independent measurements relevant to current cosmology and the number of free parameters of the theory might roughly be of the same order [86, 87]: In the 1950s, the 'Big Bang' theory had three or four free parameters to fit the few quantities of observational cosmology available at that time, primarily the Hubble–Lemaître constant and helium abundance. As cosmological information has increased—particularly with observations of CMBR anisotropies—the number of free parameters in the model has also grown. Today, the model includes around 20 free parameters, in addition to the initial conditions and other boundary conditions introduced in simulations to reproduce specific structures of the universe or astrophysical processes, such as star formation and stellar nucleosynthesis.

A similar situation also prevails in particle physics [88]. The standard particle model, for example, has around twenty parameters; it has lost its simplicity, predictive capacity, and unity [89, 90, 88]. The

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origin of many of these parameters remains unknown and, while no significant evidence for a failure of the theory has emerged so far, it may be incomplete because it does not account for facts such as the oscillations of the neutrino; it accounts for the electromagnetic, weak, and strong interactions, but fails to unify this last with the two former and is also understood to be incomplete because it does not account for gravitation or dark energy; neither does it contain any viable dark matter particle [91]. Something similar happens with cosmology. In total, it is stated that particle physics and cosmology have in total more than thirty independent fundamental constants [92].

In cosmology, for instance, the number of independent measurements in Cosmic Microwave Background Radiation anisotropies is not high. While its power spectrum shows repeated information in the form of multiple peaks and oscillations, its Fourier transform, the angular correlation function, offers a more compact presentation that condenses all the information of the multiple peaks into a localized real space feature. Oscillations in the power spectrum arise when there is a discontinuity in a given derivative of the angular correlation function at a given angular distance [93]. This allows a physical interpretation of these mathematical properties of CMBR anisotropies in terms of matter distribution in the fluid generating the radiation. A power spectrum with oscillations is a rather normal characteristic expected from any fluid with clouds of overdensities that emit/absorb radiation or interact gravitationally with photons, and with a finite range of sizes and distances for those clouds [94]. The standard cosmological interpretation of 'acoustic' peaks, from the hypothesis of primaeval adiabatic perturbations in an expanding universe [95], is just a particular case; peaks in the power spectrum might be generated in scenarios that have nothing to do with oscillations owing to gravitational compression in a fluid. The CMBR angular correlation function can be fitted by a generic function with a total of $\approx$6 free parameters. Saying that the power spectrum/angular correlation function contains hundreds or thousands of independent parameters for a given resolution is incorrect because the different values of C_ℓ are not independent in the same sense that hundreds of observations of the position and velocity of a planet do not indicate hundreds of independent parameters, the information of the orbit of a planet being reduced to six Keplerian parameters.

Today, apart from minor problems due to the goal of arriving at a 'precision' cosmology, there is near consensus in the approximate values of the cosmological parameters. There have, however, been many major historical disputes concerning the measurement of these parameters. For example, historical analyses [96, 97] show that, before 1995, there has been a great dispersion around two values (50 and 100 km s^{-1} Mpc^{-1}) of the Hubble–Lemaître constant, whereas immediately after 1995 almost all values clustered very close to a preferred value of 70 km s^{-1} Mpc^{-1} with small errors given by the HST Key Project. Measurements of Ω_Λ, a quantity that was considered null before the 1990s, have now settled at 0.7, and since 1995 it presents a dispersion much lower than expected statistically from the error bars [96], which means either that the error bars were overestimated, or that there is a bias in the publication of results towards the preferred value. Other examples could be given.

Nonetheless, in the process of refining the standard model, the controversy has abated at the cost of adding more and more ad hoc corrections and new parameters, which may be metaphorically referred to as Ptolemaic-style 'epicycles'. The development of modern cosmology bears a strong similarity to the development of the Ptolemaic epicyclic theory, a historical example brought up many times by many different authors when topics such as dark matter, dark energy, or inflation are brought up.

Alfonso the Wise (Alfonso X, king of Castile, 1221–1284), said of the Ptolemaic system: 'If the Lord Almighty had consulted me before embarking upon Creation, I should have recommended something simpler'. A similar judgement may be uttered today concerning the standard cosmological model: it is too complicated to be considered an elegant truth, while at the same time not complicated enough to accommodate all the observational evidence. In the future, therefore, we may well see the cosmologists adding new epicycles in an effort to 'save the theory'.

Even renowned defenders of the Big-Bang may admit the similarity between the dark elements of ΛCDM cosmology and the epicycles, deferents, and quadrants of the Ptolemaic model. They occasionally mention it, although half-heartedly, so as not to be confused with those heterodox researchers that loudly claim that dark matter is like an epicycle in a geocentric model. I remember—because I took notes of it, since my memory is not so good—for instance, Edward W. ('Rocky') Kolb (1951–) in a presentation wondering whether the actual cosmological model is a modern version of epicycles. I remember the brave claims of Kolb, saying ironically in his talk: 'We don't know anything about the reason for Λ, the dark matter, the particles of inflation. ... Welcome to the golden age of cosmology!'. However, this honest sentence does not appear in the published proceedings [98].

The situation is different for cosmological models different from ΛCDM. In this race to build more and more epicycles, the Big Bang model is allowed to make ad hoc corrections and add more and more free parameters to the theory in order to solve the problems that get in its way; in contrast, alternative models are summarily rejected when gaps in knowledge or inconsistencies arise, and most cosmologists do not accept their ad hoc corrections. One may wonder why different theories are accepted or rejected with such different criteria:

> If physicists do not understand the what of their theories, they'll introduce a new particle. If they don't understand the when, then it must have happened right after the Big Bang. If they don't understand the where, then of course it took place in an extra dimension. And if they don't understand the how, they will postulate a new interaction. If they don't understand the how much, a symmetry breaking will soon appear. If they don't understand anything, they will propose strings and branes. And if they lose interest in all understanding, there is always the strong anthropic principle. [Alexander Unzicker (1965–), physicist, in ch. 17 of *Bankrupting Physics* [88]]

> Given a theory A self-called orthodox or standard, and a non-orthodox or non-standard theory B. If the observations achieve what was predicted by the theory A and not by the theory B, this implies a large success to the theory A, something which must be divulged immediately to the all-important mass media. This means that there are no doubts that theory A is the right one. Theory B is wrong; one must forget this theory and, therefore, any further research directed to it must be blocked (putting obstacles in the way of publication, and giving no time for telescopes, etc.).
>
> If the observations achieve what was predicted by theory B rather than by theory A, this means nothing. Science is very complex and before taking a position we must think further about the matter and make further tests. It is probable that the observer of such had a failure at some point; further observations are needed (and it will be difficult to make further observations because we are not going to allow the use of telescopes to re-test such a stupid theory as theory B). Who knows! Perhaps the observed thing is due to effect 'So-and-so', of course; perhaps they have not corrected the data from this effect, about which we know nothing. Everything is so complex. We must be sure before we can say something about which theory is correct. Furthermore, by adding some new aspects in the theory A surely it can also predict the observations, and, since we have an army of theoreticians ready to put in patches and discover new effects, in less than three months we will have a new theory A (albeit with some changes) which will agree the data. In any case, while in troubled waters, and as long as we do not clarify the question, theory A remains. [López-Corredoira; [99]]

2.2 Social dynamics of an N-cosmologist system

Many cosmologists are used to performing simulations of astronomical objects, aimed at understanding the dynamics of the whole universe. N-body simulations are popular, especially among experts on large-scale structure. Clusters of galaxies, galaxies, or even smaller sized masses are point-like objects in the vast space simulated in mega-computers. Human beings are studied by sociologists in a similar way by looking at global trends and statistical numbers, rather than paying attention to individuals. Human behaviour is in general more complex than stellar or galactic events, but one may derive some basic laws from observing their behaviour. We cannot carry out a simulation of the evolution of humanity (or maybe we can, I am not sure how far sociology has gone in this aspect), but we can extract some rules from mere observation.

Cosmologists, along with researchers in other disciplines, are human beings and most of them are motivated by the same concerns as the rest of humanity. The dynamics of our present-day society are driven by certain forces that may be identified in terms of economic or other power structures.

2.2.1 The prestige of orthodoxy. Alternative cosmological models are not rejected because they are not potentially competitive, but because physicists developing potentially competitive alternative cosmological encounter great difficulties in advancing in their research. A small number of scientists cannot compete with the huge mass of cosmologists dedicated to polishing and refining the standard theory, which is endowed with status, power, and prestige among members of the scientific community, who dedicate large portions of their time and effort to the administration and politics of science,[6] in a struggle to be leaders of projects. In stark contrast, professional researchers who choose to challenge dominant ideas experience obstacles and ostracism, a phenomenon that has been studied by many sociologists (e.g., [101]). It is is well known within the astrophysical community that dissenters from orthodoxy pay a high price in terms of their career prospects.

[6] Elsewhere, I refer to such activities as astropolitics; see [99], [100, chs. 3, 6].

Even astrophysicists of great prestige who have spent their whole professional lives arguing in favour of orthodoxy in cosmology can fall from grace if they at a given moment depart from the consensus, even over minor questions. For instance, Allan R. Sandage (1926–2010) and Gustav A. Tammann (1932–2019) were marginalized by the system after 1999, when the community decided that a value of around 71 km/s/Mpc for the Hubble–Lemaître constant was preferable to the value of of 56-58 km s^{-1} Mpc^{-1} given by Sandage and Tammann [102].

Philosophers have also perceived how power structures are pushing research in a single direction while preventing other possible ideas from emerging. The philosopher of science Mario Bunge (1919–2020) points out a number of causes that are destroying science in the form of recipes to kill it [103]: eliminating all heterodox researchers, restricting freedom of research, subjecting ideas to strict control, rewarding mediocre researchers and punishing those who show any originality, favouring applied over basic research, putting the direction of science and technology in the hands of a public manager (a lawyer, a politician, or at most an engineer or a doctor) with no scientific experience, burdening researchers with administrative tasks so that they have little time to concentrate on science, etc. These recipes apply well to cosmology.

2.2.2 Funding of cosmology. Money distribution acts as a potential in a field that attracts particles around it, and the flows of funding have a very great impact on how science is produced.

> The snowball effect arising from the social dynamics of research funding drove more researchers into the Standard Cosmology fold and contributed to the drying out of alternative ideas [Jayant Narlikar, heterodox cosmologist co-creator of QSSC model; [104]]

The snowball effect referred to by Narlikar is also called Matthew effect, after the sociologist Robert K. Merton (1910–2003), who named after a passage from the Gospel of St. Matthew (25:29) [105]: 'Unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath.' This dictum is to a certain extent present in the social dynamics of cosmology, as well as in other speculative areas of science [100, §3.8]. It is a feedback loop: the more successful the standard theory is, the more money and scientists are dedicated to work on it, and therefore the higher the number of observations that can be explained with the help of ad hoc parameters and hypotheses, such as dark matter, dark energy and inflation. This, in turn, causes the theory to be considered more successful.

Such snow balls or looping do not continue rolling forever, especially when the dogmas defended are false, but it takes several generations to stop them and give an opportunity to other ideas. The renowned physicist Max Planck (1858–1947) said that a new scientific truth does not triumph by convincing its opponents and making them see the light; it succeeds only because its opponents die off and a new generation grows up that is familiar with it [106].

In a political context, the Pulitzer Prize-winning writer Upton Sinclair (1878–1968) quipped:

> It is difficult to get a man to understand something when his salary depends on his not understanding it. [107]

As the philosopher Paul K. Feyerabend (1924–1994) put it,

> ...the best single entity to get a modern scientist away from what his 'scientific conscience' tells him to pursue is still the dollar. [108, ch. 4]

2.2.3 Telescope time. Money can be important in the development of a scientific idea when hiring new researchers to work on it, but not only that. There are many cases where heterodox researchers self-fund the initial development of theoretical concepts, but money is an important factor in their further development, particularly when hiring new researchers to work on them. Another factor is obtaining telescope time to carry out special observations beyond the publicly available data. It is well known that heterodox cosmologists rarely get telescope time when they try to work on ideas that stray from the consensus, precisely because the committees charged with the allocation of telescope time are in the hands of researchers holding standard views, who form the majority of the research community. Since, as in democracies, the majority decides, and the standard cosmology has a much greater number of adherents, the probability of a heterodox researcher gaining access to expensive telescope time is not high.

Not only is telescope time awarded preferentially to teams with orthodox views in cosmology, but these teams' use of these expensive instruments obliges them to churn out impressive reports for the mass media aimed at the general public as if to say, 'See how your taxes have helped us to produce this fantastic science'. Ever present is the insidious temptation to exaggerate the importance of results.

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2.2.4 Rejection of papers and lack of citation. Although lack of telescope time to test certain ideas is an obstacle, it does not constitute a total hindrance since heterodox cosmologists can work on their ideas regardless. With the huge amounts of publicly available data, one may do a lot of astrophysics without the need to set foot in a telescope control room. A greater obstacle is the process of publishing scientific results, since the most important journals are usually reluctant to publish research that goes against the Big Bang theory: if the paper in question seriously challenges the status quo in cosmology, either the referees reject it with no possibility of reply, or the editors of the journal reject it themselves without even sending it to a referee. There are exceptions of this behaviour, but they are rare. The only other possibilities open to heterodox (professional or non-professional) cosmologists is to disseminate their articles by publishing them either in very minor journals that are usually ignored by professional cosmologists or in sundry Internet forums in the vast ocean of amateur ideas.

Not all alternative ideas in cosmology encounter the same level of rejection. Ideas that we might classify as variations on the standard model (see §2.1; e.g., MOND, $R_h = ct$,...) have a better chance of acceptance than other, more extreme positions, such as those claiming the possibility of a static universe, which are usually rejected outright after reading the title or abstract. In recent years, after the introduction of dark energy in cosmology, the tolerance range has become narrower and narrower. This highly restrictive editorial choice of articles deemed worth of publication creates the false sensation that there is overwhelming evidence in support of ΛCDM and promotes to the impression that the alternative ideas are either dead or maintained by a few rank outsiders.

An even greater obstacle is the lack of attention that the few accepted publications receive. Most cosmologists simply look aside when they find a paper arguing against the standard model or proposing new ideas.

2.2.5 Censorship at arXiv.org. Apart from the refereed journals, another important tool for communicating scientific results in physics is the preprint server *arXiv.org*. Its lack of competitors gives it a monopolistic role in physics publishing. Other preprint servers are usually ignored by most astrophysicists. The majority of papers published in journals are posted on this preprint server [109], and it serves as the first port of call for astrophysicists. The situation has evolved such that papers not posted on arXiv.org receive scant dissemination within the community, particularly when the papers are not published in a reputed refereed journal, which is often the case for non-mainstream positions.

The development of *arXiv.org*, first at Los Alamos National Laboratory and later at Cornell University, was a wonderful example of freedom of expression between 1992 to 2004 that provided everybody with an open forum in which to post their ideas. There was a small fraction of papers with 'exotic' ideas, but they were very few (5% or less), so they did not disturb the flow of information. However, after 2004 there was a change in policy and those responsible for the site decided to block the posting of certain contributions. In 2004, a system was introduced requiring support from a colleague with experience in the field in order to post something on the site. The methods of the system would become more subtle in the following years, forbidding some scientists from giving support when arXiv moderators noted that they had allowed the publication of very challenging heterodox ideas. Committees were created for the purpose of rejecting papers without any obligation to read or comment them: the committees just read the title and the abstract and, if they do not like the content (and normally they do not like anything that has not been accepted in a refereed journal and smells of heterodoxy, such as denial of the expansion of the universe or discussions concerning alternative interpretations of the CMBR), they shunt the paper, which formerly would have been placed on 'astro-ph.CO', widely read by astrophysicists, to 'physics.gen-ph', which is hardly read by anybody. In some cases, they remove the contribution totally, without further explanation (e.g., [110]). When asked for an explanation for a rejection, they usually reply with set phrases: 'arXiv reserves the right to reclassify or reject any submission. We are not obligated to provide substantive reasons for every rejection, and usually the moderators do not provide more than a sentence or two, often in a form not appropriate for author viewing'.

2.2.6 Conferences. Last, but not least, is the conference circuit for spreading scientific results. Here it is common to find people with outrageous ideas, yes. Nonetheless, they do not occupy the best places (invited reviews, plenary lectures, etc.) and, if they are allowed to present a short oral communication or a poster, the attendees pay almost no attention to them. The physicist Robert B. Leighton (1919–1997), talking about conferences, once said that scientists seldom listen to other scientists, and if they are dozing to lectures, they may be preoccupied by their own thoughts [111]. Conferences are not places to do science by promoting new ideas, but rather sites where people meet colleagues over a beer to discuss the social issues of science, or form collaborations among groups of people with similar ideas. A heterodox cosmologist at a conference with a vast majority of orthodox cosmologists, who are also usually

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the organizers, will receive very little or no attention at all. Precisely because of that, the organizers try to avoid the formation of big groups with heterodox ideas, because they know that an isolated individual will have little effect, whereas a group of scientists with common ideas may have a considerable impact.

Some alternative theories may be marginal and dead, not because irrefutable scientific arguments against them have been given, but rather precisely because of this kind of attitude in the organization of social scientific events (journals, meetings, etc.). Alternative theories die because they are being killed off by the same people who declare them to be dead. Most of the scientists who claim that these theories are dead or marginal have never read a paper on these ideas and are merely repeating what they have heard from some colleague. Indeed, what the censors probably mean is that the leaders of alternative ideas in cosmology are passing away before they gain any recognition and their work is not handed on to new generations, so it is understood that there is now no living sacred cow to respect, with the result that the community decides to declare that the alternative theories are dead.

Heterodox cosmologists also organize their own conferences, where freedom to challenge the standard model is considered a plus. These events, however, are not usually supported by funds from any organization within astrophysics, they have small number of participants, they lack impact among other cosmologists and the mass media, and no important collaborations can emerge from these meeting for two reasons: 1) each heterodox cosmologist thinks that his or her model is the right one and is not interested in other ideas; and 2) there is no money to hire students or postdocs, or to organize future science. Rather, these conferences of heterodox cosmologists are venues of illusions in a parallel universe, far from the social reality that moves the funds for investment in cosmology.

2.2.7 Groupthink. How might we best explain the behaviour of the scientific community as described in the previous subsections?

The psychologist Irving Lester Janis (1918–1990) described the symptoms of groupthink, or following a leader's opinion [112, 113]. Orthodox cosmology has an important element of groupthink [114]. Any opinion, however outrageous, can be accepted if it is supported by the leading cosmologist, and in this sense the Big Bang theory, even if it is a very speculative set of hypotheses, still finds a place in the psychology of the wider community of scientists.

The psychological profile of a researcher can produce leanings towards either orthodoxy or heterodoxy. According to Luminet [115], there are two kinds of scientists: the craftsmen who do normal science (95% in string theory) and the imaginative artists of revolutionary science, with an added element of narcissism. Cosmologists tend to fall into one of the two extreme categories, although there are gradations of grey between groupthink and individualistic social forces.

Sunstein's analysis [116] of 'conformity',[7] (highly relevant in our social media age) applies to social dynamics in the sciences. Conformity dynamics is particularly pronounced when it comes to dealing with very difficult problems. Social experiments in a multitude of contexts clearly show that when the problem before us is hard to solve, as in cosmology, people tend to follow the crowd, and those who are perceived as authorities on the matter. A key mechanism in this collective effect is so-called informational cascades, where people primarily rely on the signals conveyed by others rather than on independent information. 'Once this happens, the subsequent statements or actions of few or many others add no new information. They are just following their predecessors.' [116]. This cascade is very hard to stop, as we know from social networks in the Internet. A reputational cascade develops alongside with the informational cascade and reinforces it. At this stage it simply becomes too risky to go against core consensus.

We could cite here the *Novum Organum* by the English philosopher Francis Bacon (1561–1626):

> The human understanding when it has once adopted an opinion (either as being the received opinion or as being agreeable to itself) draws all things else to support and agree with it. And though there be a greater number and weight of instances to be found on the other side, yet these it either neglects and despises, or else by some distinction sets aside and rejects; in order that by this great and pernicious predetermination the authority of its former conclusions may remain inviolate. (ch. XLVI)

2.3 Pluralism

The Austrian physicist Ludwig Boltzmann (1844–1906) defended the idea of pluralism in science [117, 118]; that is, maintaining discussion of the explanation of certain phenomena from the points of view of different theories. But pluralism is not very common. Other social ideas within scientific power hierarchies

[7]See the book review 'Big Bang Conformity?' by Bjørn Ekeberg, at the blog https://www.drbjorn.com/post/big-bang-conformity

usually dominate the development of a science. This is partly good because science achieves consensus and avoids sterile discussions that do not lead anywhere, as often occurs in many humanistic approaches. However, the positive side only arises in cases where there really is a close match between a scientific theory and reality. In cases where incorrect theories are chosen as standard views to the exclusion of others, or in fields like cosmology where a complete truth may never be reached, the negative effect of dogmatism is the stagnation of intellectual activity over the generations. This misdirection of time and resources in the wrong direction may be remembered in future generations as a significant blunder. A pluralistic approach of wrong ideas has, at the very least, the advantage of fostering an open-minded attitude and is one which deserves much greater respect.

Philosophers of science usually bet on a science with multiple theories concerning the same events, as we must remember that the truth is not always on the side of those with the most persuasive arguments. Here are some quotations from two of the most influential thinkers in the philosophy of science from the second half of the 20th century, Karl Popper (1902–1994) and Paul K. Feyerabend (1924–1994):

> [T]he orthodoxy produced by intellectual fashions, specialization, and the appeal to authorities is the death of knowledge, ... the growth of knowledge depends entirely on disagreement. [Popper; [119, p. x]]

> Intolerant dogmatism, however, is one of the main obstacles to science. Indeed, we should not only keep alternative theories alive by discussing them, but we should systematically look for new alternatives. And we should be worried whenever there are no alternatives—whenever a dominant theory becomes too exclusive. The danger to progress in science is much increased if the theory in question obtains something like a monopoly. [Popper; [119, p. 16]]

> [T]o use alternatives only when refutations have already discredited the orthodox theory puts the cart before the horse. [Feyerabend; [108, ch. 2]]

> Knowledge so conceived is not a series of selfconsistent theories that converges towards an ideal view; it is not a gradual approach to the truth. It is rather an ever increasing ocean of mutually incompatible alternatives, each single theory, each fairy-tale, each myth that is part of the collection forcing the others into greater articulation and all of them contributing, via this process of competition, to the development of our consciousness. [Feyerabend; [108, ch. 2]]

Feyerabend [108] also asserts that pluralism is the only method with a humanistic approach, with all other methods following a tyrannical or fanatical path. However, I find Feyerabend's approach in this book overly relativistic, treating all hypotheses in science and other areas as having equal value. I disagree with the notion that certain ideas, such as flat Earth proposals, geocentric cosmogony, or creationist claims about the Earth being six thousand years old, should be discussed on the same level as the widely accepted ideas of a quasi-spherical Earth, heliocentrism, and the scientific arguments supporting a much older Earth. There are many theories in science that have so solid basis as to be considered definitive, such that they no longer require continuous discussion.

However, there are areas, such as cosmology, where speculation still prevails and where many inconsistencies continue to arise; in such cases the pluralism proposed by Feyerabend and other philosophers of science is appropriate. As explained throughout this section, that is not the approach dominating cosmological research today, but it is the one that mostly reflects the current scientific spirit.

However, in areas such as cosmology, where speculation still prevails and where many inconsistencies continue to arise, the pluralism proposed by Feyerabend and other philosophers of science is appropriate. It reflects the scientific spirit. Regrettably, as pointed out throughout this section, pluralism is not the approach dominating cosmological research today.

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References

[1] López-Corredoira M 2022 *Fundamental Ideas in Cosmology. Scientific, philosophical and sociological critical perspectives* (Bristol: IOP Publishing)

[2] Peebles P J E 1993 *Principles of Physical Cosmology* (Princeton: Princeton Univ. Press)

[3] Baryshev Y V, Sylos Labini F, Montuori M and Pietronero L 1994 Facts and ideas in modern cosmology *Vistas in Astronomy* **38** 419–500

[4] Gabrielli A, Sylos Labini F, Joyce M and Pietronero L 2005 *Statistical Physics for Cosmic Structures* (Berlin: Springer Verlag)

[5] Layzer D 1990 *Cosmogenesis* (Oxford: Oxford University Press)

[6] Aguirre A N 1999 Cold Big Bang nucleogenesis *Astrophys. J.* **521** 17–29

[7] Aguirre A N 2000 The cosmic background radiation in cold big bang *Astrophys. J.* **533** 1–18

[8] Goldman T, Pérez-Mercader J, Cooper F and Nieto M M 1992 The dark matter problem and quantum gravity *Phys. Lett. B* **281** 219–224

[9] Albrecht A and Magueijo J 1999 Time varying speed of light as a solution to cosmological puzzles *Phys. Rev. D* **59** id. 043516, 13 pp.

[10] Shojaie H and Farhoudi M 2004 A cosmology with variable c *Canadian J. Phys.* **84(10)** 933–944

[11] Ellis G R 2007 Note on varying speed of light cosmologies *General Relativity and Gravitation* **39** 511–520

[12] Miller R I 2021 Altu: The alternative universe *viXra.org* p. 2102.0009

[13] Unzicker A 2015 *Einstein's Lost Key: How We Overlooked the Best Idea of the 20th Century* (CreateSpace Independent Publishing Platform)

[14] Gupta R P 2020 Cosmology with relativistically varying physical constants *Mon. Not. R. Astron. Soc.* **498** 4481–4491

[15] Gohar H 2017 Cosmology with varying constants from a thermodynamic viewpoint *Universe* **3** 26

[16] Clifton T, Ferreira P G, Padilla A and Skordis C 2012 Modified gravity and cosmology *Phys. Reports* **513**(1) 1–189

[17] Sanders R H and McGaugh S S 2002 Modified Newtonian Dynamics as an alternative to dark matter *Annu. Rev. Astron. Astrophys.* **40** 263–317

[18] Famaey B and McGaugh S 2012 Modified Newtonian Dynamics (MOND): Observational phenomenology and relativistic extensions *Living Rev. Relativity* **15** id. 10, 159 pp.

[19] Sanders R H 2015 A historical perspective on Modified Newtonian Dynamics *Canadian J. Phys.* **93** 126–138

[20] Merritt D 2020 *A philosophical approach to MOND. Assessing the Milgromian Research Program in Cosmology* (Cambridge: Cambridge Univ. Press)

[21] Bekenstein J and Milgrom M 1984 Does the missing mass problem signal the breakdown of Newtonian gravity? *Astrophys. J.* **286** 7–14

[22] Milgrom M 2010 Quasi-linear formulation of mond *Mon. Not. R. Astron. Soc.* **403** 886–895

[23] Bekenstein J D 2004 Relativistic gravitation theory for the Modified Newtonian Dynamics paradigm *Phys. Rev. D* **70** id. 083509

[24] Moffat J W 2006 Scalar tensor vector gravity theory *J. Cosmol. Astropart. Phys.* **2006(3)** id. 004

[25] Sotiriou T P and Faraoni V 2010 $f(R)$ theories of gravity *Rev. Mod. Phys.* **82** 451–497

[26] Krasnov K and Shtanov Y 2008 Non-metric gravity: II spherically symmetric solution, missing mass and redshifts of quasars *Class. Quantum Grav.* **25** id. 5002

[27] Annila A 2016 Rotation of galaxies within gravity of the universe *Entropy* **18** 191

[28] Jackson L S 2014 *Weyl Conformal Gravity: Tests and New Solutions* (Chisinau: Lambert Academic Publishing)

[29] Felten J E 1984 Milgrom's revision of Newton's laws - dynamical and cosmological consequences *Astrophys. J.* **286** 3–6

[30] Sanders R H 1998 Cosmology with Modified Newtonian Dynamics (MOND) *Mon. Not. R. Astron. Soc.* **296** 1009–1018

[31] Sanders R H 2006 MOND and cosmology *Mass Profiles and Shapes of Cosmological Structures (EAS Publ. Ser. 20)*, eds G A Mamon, F Combes, C Deffayet and B Fort (Les Ulis Cedex: EDP Sciences) pp. 231–238

[32] Görnitz T 1988 Connections between abstract quantum theory and space-time structure II. a model of cosmological evolution *Int. J. Theor. Phys.* **27** 659–666

[33] John M V and Joseph K B 1996 A modified ozer-taha type cosmological model *Phys. Lett. B* **387** 466–470

[34] Melia F and Shevchuk A S 2012 The $R_h = ct$ universe *Mon. Not. R. Astron. Soc.* **419** 2579–2586

[35] Melia F and López-Corredoira M 2017 Alcock-Paczyński cosmological test with model-independent BAO data *Int. J. Mod. Phys. D* **26** id. 1750055, 10 pp.

[36] Melia F 2017 The zero active mass condition in Friedmann-Robertson-Walker cosmologies *Frontiers of Phys.* **12** 129802, 5 pp.

[37] Melia F 2019 Cosmological test using the Hubble diagram of high-z quasars *Mon. Not. R. Astron. Soc.* **489** 517–523

[38] Planck Collaboration c 2020 Planck 2018 results. VI. Cosmological parameters *Astron. Astrophys.* **641** id. A6, 67 pp.

[39] Melia F 2020 Reassesing dust's role in forming the CMB *Eur. Phys. J. Plus* **135** id. 511

[40] Penrose R 2010 *Cycles of Time: An Extraordinary New View of the Universe* (London: Bodley Head)

[41] Steinhardt P J and Turok N 2008 *Endless Universe. Beyond the Big Bang* (London: Orion)

[42] Segal I E 1976 *Mathematical Cosmology and Extragalactic Astronomy* (New York: Academic Press)

[43] Segal I E and Zhou Z 1995 Maxwell's equations in the Einstein universe and chronometric cosmology *Astrophys. J. Supp. Ser.* **100** 307–324

[44] Sandage A and Tammann G A 1995 Steps toward the Hubble constant. X. the distance of the Virgo cluster core using globular clusters *Astrophys. J.* **446** 1–11

[45] Salpeter E E and Hoffman G L 1986 The galaxy luminosity function and the redshift-distance controversy (a review) *Proc. US Nat. Acad. Sci.* **83** 3056–3063

[46] Wright E L 1987 Source counts in the chronometric cosmology *Astrophys. J.* **313** 551–555

[47] Sandage A 1992 Evidence that the expansion is real *Phys. Scr.* **T43** 22–30

[48] Koranyi D M and Strauss M A 1997 Testing the Hubble law with the IRAS 1.2 Jy redshift survey *Astrophys. J.* **477** 36–46

[49] Almeida J 2006 Geometric drive of the universe's expansion *1st Crisis in Cosmology Conference (AIP Conf. Ser. 822(1))*, eds E J Lerner and J B Almeida (Melville: AIP) pp. 110–122

[50] Netchitailo V S 2020 World-universe model–alternative to big bang model *J. High Energy Phys., Gravit. Cosmol.* **6** 133–158

[51] Netchitailo V S 2021 Hypersphere world-universe model *J. High Energy Phys., Gravit. Cosmol.* **7** 915–941

[52] Suntola T 2018 *The Dynamic Universe (4th. ed)* (Helsinki: Physics Foundations Society and The Finnish Society for Natural Philosophy)

[53] Suntola T 2020 Unification of theories requires a postulate basis in common *J. Phys. Conf. Ser.* **1466** id. 012003, 27 pp.

[54] Hoyle F 1948 A new model for the expanding universe *Mon. Not. R. Astron. Soc.* **108** 372–382

[55] Bondi H and Gold J 1948 The steady-state theory of the expanding universe *Mon. Not. R. Astron. Soc.* **108** 252–270

[56] O'Raifeartaigh C, McCann B, Nahm W and Mitton S 2014 Einstein's steady-state theory: an abandoned model of the cosmos *Eur. Phys. J. H* **39** 353–367

[57] Burbidge E M, Burbidge G R, Fowler W A and Hoyle F 1957 Synthesis of the elements in stars *Rev. Mod. Phys.* **29** 547–650

[58] Ryle M and Clarke R W 1961 An examination of the steady-state model in the light of some recent observations of radio sources *Monthly Notices of the Royal Astronomical Society* **122** 349–362

[59] Hoyle F, Burbidge G and Narlikar J V 1993 A quasi-steady state cosmological model with creation of matter *Astrophys. J.* **410** 437–457

[60] Hoyle F, Burbidge G and Narlikar J V 1994 Astrophysical deductions from the quasi steadystate cosmology *Mon. Not. R. Astron. Soc.* **267** 1007–1019

[61] Hoyle F, Burbidge G R and Narlikar J V 2000 *A different approach to Cosmology* (Cambridge: Cambridge Univ. Press)

[62] Narlikar J V, Burbidge G and Vishwakarma R G 2007 Cosmology and cosmogony in a cyclic universe *J. Astrophys. Astron.* **28** 67–99

[63] Nayeri A, Engineer S, Narlikar J V and Hoyle F 1999 Structure formation in the quasi-steady state cosmology: A toy model *Astrophys. J.* **525** 10–16

[64] Wright E L 1995 Comments on the quasi-steady-state cosmology *Mon. Not. R. Astron. Soc.* **276** 1421–1424

[65] Hoyle F, Burbidge G and Narlikar J V 1995 The quasi-steady-state cosmology: a note on criticisms by E. L. Wright *Mon. Not. R. Astron. Soc.* **277** L1–L3

[66] Wickramasinghe N C 2006 Evidence for iron whiskers in the universe *Current issues in Cosmology*, eds J C Pecker and J V Narlikar (Cambridge (U. K.): Cambridge University Press) pp. 152–163

[67] Narlikar J V, Vishwakarma R G, Hajian A, Souradeep T, Burbidge G and Hoyle F 2003 Inhomogeneities in the microwave background radiation interpreted within the framework of the quasi-steady state cosmology *Astrophys. J.* **585** 1–11

[68] Hoyle F and Wickramashinghe N C 1988 Metallic particles in astronomy *Astrophys. Space Sci.* **147** 245–256

[69] Ibison M 2006 Thermalization of starlight in the steady-state cosmology *1st Crisis in Cosmology Conference (AIP Conf. Ser. 822(1))*, eds E J Lerner and J B Almeida (Melville: AIP) p. 171

[70] Alfvén H and Klein O 1962 Matter-antimatter annihilation and cosmology *Arkiv för fysik* **23** 187

[71] Alfvén H 1983 On hierarchical cosmology *Astrophys. Space Sci.* **89** 313–324

[72] Alfvén H 1988 Cosmology in the plasma universe *Laser and Particle Beams* **16** 389–398

[73] Lerner E J 1991 *The Big Bang never happened: a startling refutation of the dominant theory of the origin of the universe* (Toronto: Random House)

[74] Alfvén H 1981 *Cosmic Plasma (Astrophysics and Space Science Library, vol. 82)* (Dordrecht: Reidel)

[75] Peratt A L 1983 Are black holes necessary? *Sky & Telescope* **66** 19–22

[76] Peratt A L 1984 Simulating spiral galaxies *Sky & Telescope* **68** 118–122

[77] Alfvén H 1979 Hubble expansion in a euclidean framework *Astrophys. Space Sci.* **66** 23–27

[78] Lehnert B 1977 Problems of matter-antimatter boundary layers *Astrophys. Space Sci.* **46** 61–71

[79] Rogers S and Thompson W B 1980 In defense of anti-matter *Astrophys. Space Sci.* **71** 257–260

[80] Brynjolfsson A 2004 Redshift of photons penetrating a hot plasma *arXiv.org* pp. astro–ph/0401420

[81] Lerner E J 2006 Evidence for a non-expanding universe: Surface brightness data from HUDF *1st Crisis in Cosmology Conference*, eds E J Lerner and J B Almeida (Melville (2006: AIP Conf. Ser. 822(1)). AIP) pp. 60–74

[82] Lerner E J 1988 Plasma model of microwave background and primordial elements - an alternative to the big bang *Laser and Particle Beams* **6** 457–469

[83] Lerner E J 1995 Intergalactic radio absorption and the COBE data *Astrophys. Space Sci.* **227** 61–81

[84] Yang J L 2016 Modification of field equation and return of continuous creation – galaxies form from gradual growth instead of gather of existent matter *Int. J. Advanced Res. Phys. Sci.* **3(8)** 5–32

[85] Ćirković M M and Perović S 2018 Alternative explanations of the cosmic microwave background: a historical and epistemological perspective *Studies in History and Philosophy of Modern Physics* **62** 1–18

[86] Disney M J 2007 Modern cosmology: Science or folktale? *American Scientist* **95**(5) 383–385

[87] Disney M J 2011 Doubts about big bang cosmology *Aspects of Today's Cosmology*, ed A Alfonso-Faus (INTECH Open Access Publisher) pp. 123–132

[88] Unzicker A and Jones S 2013 *Bankrupting Physics. How today's top scientists are gambling away their credibility* (New York: Palgrave)

[89] Smolin L 2008 *The Trouble with Physics: The Rise of String Theory, The Fall of Science, and What Comes Next* (Boston (Massachusets): Houghton Mifflin Hartcourt)

[90] Iradier M 2009 *La ciencia en coordenadas* (Cádiz: Hurqualya)

[91] Yao W M, Amsler C, Asner D et al. 2006 Review of particle physics *J. Phys. G: Nuclear and Particle Phys.* **33** 1–1232

[92] Tegmark M, Aguirre A, Rees M J and Wilzek F 1998 Dimensionless constants, cosmology, and other dark matters *Phys. Rev. D* **73** id. 023505,

[93] López-Corredoira M and Gabrielli A 2013 Peaks in the CMBR power spectrum. I. Mathematical analysis of the associated real space features *Physica A* **392** 474–484

[94] López-Corredoira M 2013 Peaks in the CMBR power spectrum II: Physical interpretation for any cosmological scenario *Int. J. Mod. Phys. D* **22**(7) id. 1350032

[95] Peebles P J E and Yu J T 1970 Primeval adiabatic perturbation in an expanding universe *Astrophys. J.* **162** 815–836

[96] Croft R A C and Dailey M 2015 On the measurements of cosmological parameters *Quarterly Phys. Rev.* **1** 1–14

[97] Faerber T and López-Corredoira M 2020 A chi-squared analysis of the measurements of two cosmological parameters over time *Universe* **6** 114

[98] Kolb E W 2001 Cosmology at the start of a new century *Historical Development of Modern Cosmology (ASP Conf. Ser. 252)*, eds V J Martínez, V Trimble and M J Pons-Bordería (S. Francisco: The Astronomical Society of the Pacific) pp. 295–307

[99] López-Corredoira M 2008 What do astrophysics and the world's oldest profession have in common? *Against the Tide. A Critical Review by Scientists of How Physics and Astronomy Get Done*, eds M López-Corredoira and C Castro Perelman (Boca Raton (FL, USA): Universal Publishers) pp. 145–177

[100] López Corredoira M 2013 *The Twilight of the Scientific Age* (Boca Raton (FL, USA): BrownWalker Press)

[101] Campanario J M and Martin B 2004 Challenging dominant physics paradigms *J. Sci. Exploration* **18** 421–438

[102] Burbidge G R 2006 The state of cosmology *Current issues in Cosmology*, eds J C Pecker and J V Narlikar (Cambridge (U.K.): Cambridge University Press) pp. 3–16

[103] Bunge M 1997 *Ciencia, técnica y desarrollo* (Buenos Aires: Ed. Sudamericana)

[104] Narlikar J V and Padmanabhan T 2001 Standard cosmology and alternatives: A critical appraisal *Annu. Rev. Astron. Astrophys.* **39** 211–248

[105] Merton R K 1968 The Matthew effect in science *Science* **159** 56–63

[106] Planck M 1949 *Scientific autobiography and other papers* (London: Williams & Norgate)

[107] Singer D W 1935 *I, candidate for governor: and how I got licked* (New York: Farrar, Strauss and Giroux)

[108] Feyerabend P K 1975 *Against method* (London: New Left Books)

[109] Henneken E A, Kurtz M J, Eichhorn G, Accomazzi A, Grant C, Thompson D and Murray S S 2006 Effect of e-printing on citation rates in astronomy and physics *J. Electronic Publishing* **9(2)**

[110] Castro Perelman C 2008 My struggle with Ginsparg (arxiv.org) and the road to Cyberia: A scientific-gulag in cyberspace *Against the Tide. A Critical Review by Scientists of How Physics and Astronomy Get Done*, eds M López-Corredoira and C Castro Perelman (Boca Raton (FL, USA): Universal Publishers) pp. 59–76

[111] Leighton R B 1971 Panel discussions: Is there any hope? *Phys. Today* **24** 30

[112] Janis I L 1972 *Groupthink: psychological studies of policy decision and fiascos* (Boston (MA, USA): Houghton Mifflin)

[113] Dolsenhe O 2011 *A Critique of Science: How Incoherent Leaders Purged Metaphysics of Mind and God* (Raleigh (NC, USA): Lulu)

[114] Sanromà M 2007 *El Big Bang: història i sociologia d'una teoria científica* Master's thesis Universidad Oberta de Catalunya

[115] Luminet J P 2008 Is science nearing its limits? summarizing dialogue *Is science nearing its limits?*, eds G Steiner, E Rui Vilar, F ao Calouste Gulbenkian et al. (Manchester: Carcanet Press) pp. 180–200

[116] Sunstein C R 2019 *Conformity: The Power of Social Influences* (New York: New York Univ. Press)

[117] Hiebert E N 1980 Boltzmann's conception of theory construction: The promotion of pluralism, provisionalism, and pragmatic realism *Probabilistic Thinking, Thermodynamics and the Interaction of the History and Philosophy of Science (Synthese Library: Studies in Epistemology, Logic, Methodology, and Philosophy of Science, vol 146)*, eds J Hintikka, D Gruender and E Agazzi (Dordrecht: Springer) pp. 175–198

[118] Ribeiro M B and Videira A A P 1998 Dogmatism and theoretical pluralism in modern cosmology *Apeiron* **5** 227–234

[119] Popper K 1994 *The myth of a framework: in defence of science and rationality* (London: Routledge)